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STUDIES ON THE SIZES, SHAPES, AND THE DEVELOPMENT OF THE LORICA OF AGGLUTINATED TINTINNIDA[1]

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The ciliates, Tintinnida, are well known to be capable of accumulating particulate substances on their loricae. Gold and Morales (1976), using scanning electron microscopy, demonstrated that there were obvious differences in the nature of the particles that were utilized by members of the genera *Stenosemella and Tintinnopsis*. The former produced loricae that were distinctly arenaceous and composed principally of mineral particles of nonbiological origin; *Tintinnopsis tubulosoides* appeared to be agglutinated with nonbiogenic grains and flakes, but also with numerous fragments of biogenic material such as protozoan shells, coccoliths and diatom frustules. The significance of the differences in the materials utilized by species of the two genera, was suggested to lie in developmental processes and in the location where the loricae were produced, *e.g.*, the sediments or the water column. It followed from that hypothesis that the types of materials utilized should be of evolutionary and taxonomic importance. From another point of view, the agglutinating species have the potential of concentrating insoluble minerals directly, or soluble forms sorbed to silt-sized particles. This route may be one in which minerals are moved along the food chain to humans, hence there is a practical need to identify the substances that are commonly utilized by agglutinating Tintinnida in diverse habitats.

This communication deals with three aspects of tintinnid biology concerning the shapes, sizes, and the development of the loricae. First, with the aid of scanning electron microscopy, the agglutinated species of the Woods Hole, Massachusetts region are characterized according to the nature of the particles accumulated and the apparent methods of lorica construction. Second, daily differences are reported in the mean length of the loricae in populations of *Tintinnopsis acuminata*. Third, varieties and atypical loricae of the same species are identified for some common forms.

The following terminology is used here to describe particle accumulation in the lorica development process: *agglutination* refers to the process of accumulation of particles regardless of the source and types of materials utilized. *Arenaceous* refers to the appearance of a lorica that was produced predominantly of mineral grains. The grains appear to be cemented together by what may be an active process; such forms could have an underlying organic matrix present. A lorica is considered to be agglomerated if it has both mineral grains and a large proportion of fragments of biological origin adhering to it. Agglomerated loricae differ from the arenaceous types in the amount of biogenic material present and in their

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TABLE I

Species of Tintinnida of the Woods Hole region, June–August, 1974–1975. The numerically important species during 1975 are indicated by an asterisk.

Family Tintinnididae
*Tintinnidium fluviatile**
Family Codonellidae
*Tintinnopsis acuminata**
T. baltica
*T. dadayi**
*T. levigata**
*T. minuta**
T. nucula
*T. platensis**
T. radix
*T. rapa**
*T. sufflata**
T. vasculum
Family Codonellopsidae
*Stenosemella oliva**
*S. ventricosa**
Family Coxliellidae
Helicostomella subulata
Metacylis (2 species) (Figure 3m)*
Family Ptychocylididae
Favella ehrenbergii
Family Tintinnidae
*Tintinnus angustatus**
*T. pectinis**

appearance—the particles on the loricae of agglomerated species seem to have been taken up randomly.

MATERIALS AND METHODS

Specimens were collected by hand-towing a twelve inch diameter plankton net (mesh size 20 μm) from the supply dock at the Marine Biological Laboratory, Woods Hole, Massachusetts (Eel Pond), and from the pump pier extending into Great Harbor. Samples used to identify species and for measurements were preserved either in Schaudinn's solution or $\sim$ 10% formaldehyde in sea water; specimens prepared for scanning electron microscopy (SEM) were generally selected from the samples live and micropipetted into a suitable killing agent such as Schaudinn's solution or Karnovsky's fixative (1965).

Measurements of loricae were made on wet specimens contained in a Sedgewick-Rafter counting chamber using a Wild M-20 microscope equipped with an ocular micrometer.

Specimens to be examined by SEM were thoroughly rinsed in glass distilled water, by micropipetting the cells through at least five 1 ml changes of water. Rinsed specimens were usually dried in air on cover glasses or in a Sorvall critical point drying system. Specimens were either left on the cover glasses or placed

on double coated Scotch tape, attached to a specimen mount, and then coated with 200 Å of gold/palladium alloy in a Tousimis Samsputterer. Finally, specimens were examined and photographed in a JEOL JSM-35 scanning electron microscope.

Loricae that were used in electron probe analysis were from formaldehyde-killed cells that had been thoroughly rinsed in distilled water before being mounted on spectroscopically pure carbon specimen mounts. Analysis for minerals was then performed in a JEOL JSM-U3 scanning electron microscope equipped with an Ortec energy dispersive probe microanalyzer.

Results

The species of Tintinnida that were collected in the Woods Hole, Massachusetts region during June to August 1974–1975 are listed in Table I. The table includes all of the species encountered. With the exception of *Favella ehrenbergii,* all of the species found in 1974 were present in 1975; seven additional species not detected in 1974 were present in 1975 (Gold, 1974; Gold and Morales, 1975b).

A greater variety of species was found in Great Harbor, considered here to be a neritic well-mixed environment, compared with Eel Pond—a relatively protected habitat. When the species estimated to be numerically important in both habitats were plotted according to the day of their occurrence, the pattern was a recurring one for most of the species, indicating the presence of endemic populations in these waters at that time of the year. Some species were conspicuous by the absence of a recurring pattern. In Eel Pond, for example, a *T. dadayi* population appeared suddenly, remained for approximately two weeks, then suddenly disappeared. A similar pattern was seen for *Metacylis* sp. and *Tintinnus angustatus* in Great Harbor. Abrupt disappearances of populations are recorded here for *T. rapa* in Eel Pond and for *T. sufflata* and *T. levigata* in Great Harbor. The occurrence of species seemed unrelated to water temperature in Eel Pond (Fig. 1).

A daily difference was found in the mean length of *T. acuminata* loricae in Eel Pond. Figure 2 shows a comparison of the mean length of the lorica and the standard error of the mean during periods of relatively high abundance in 1974 and 1975. The data were plotted with reference to the day on which the maximum

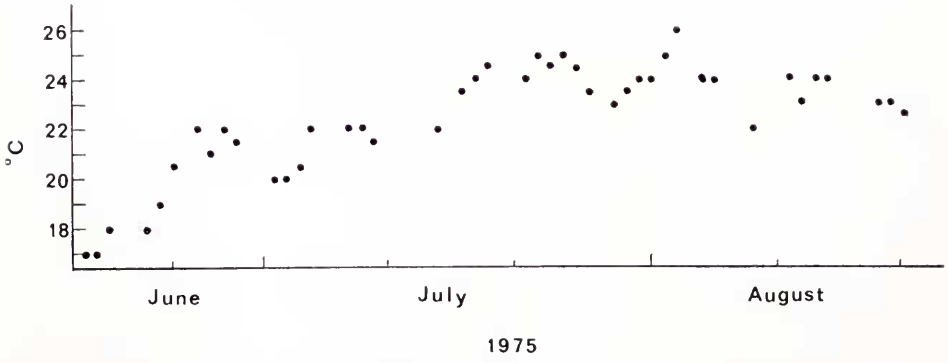

Figure 1. Water temperature at the surface in Eel Pond, 1975.

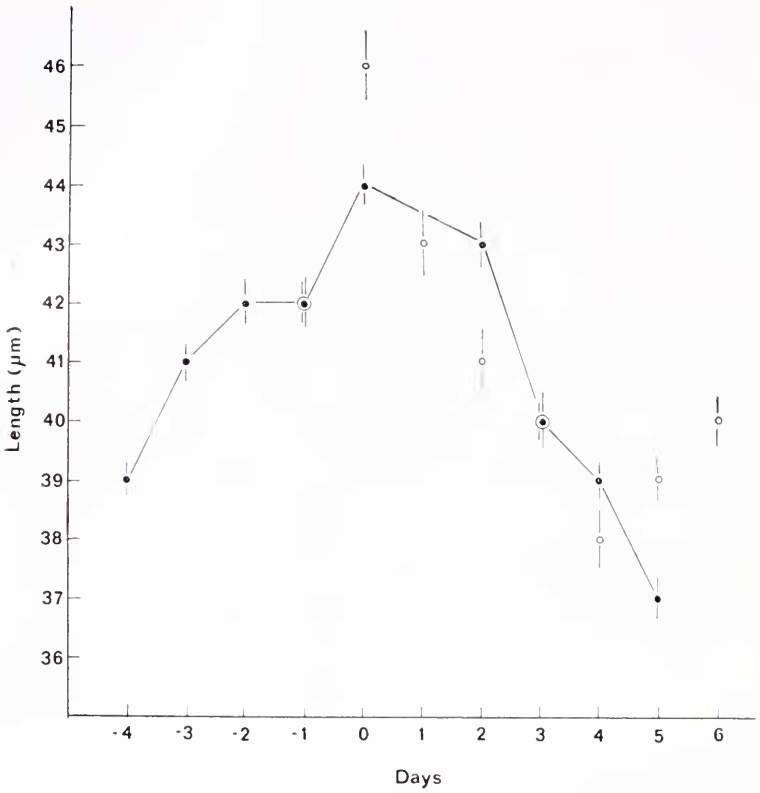

FIGURE 2. Daily mean length and the standard error for two populations of *T. acuminata*. Open circles indicate 1974; closed circles, 1975.

mean length was detected (day zero) so that the shapes of the curves could be compared quickly. The day-to-day differences were clear-cut, thus obviating the need to subject the dimensions to statistical analysis for significance.

Polymorphic varieties of loricae were detected in the plankton (Fig. 3). Besides these polymorphic varieties, atypical forms of one species were found, which are interpreted as developmental stages in lorica building. The normally developed, mature form of the lorica of *T. dadayi* is shown in Figure 8; Figure 9 is an advanced two-flare stage. Specimens such as the latter, as well as others with tubular extensions and three flares, were present in large enough numbers to warrant their being viewed as normal constituents of the plankton. Specimens were also found that lacked a flare; these were probably immature forms and accounted for a maximum of 12% of one *T. dadayi* population.

The pertinent dimensions used to identify the Woods Hole Tintinnida follow. The principal dimension used to identify forms of a lorica that were similar was the diameter of the cylindrical portion of the bowl. This dimension was found previously to be a very stable feature of the lorica structure (Gold and Morales,

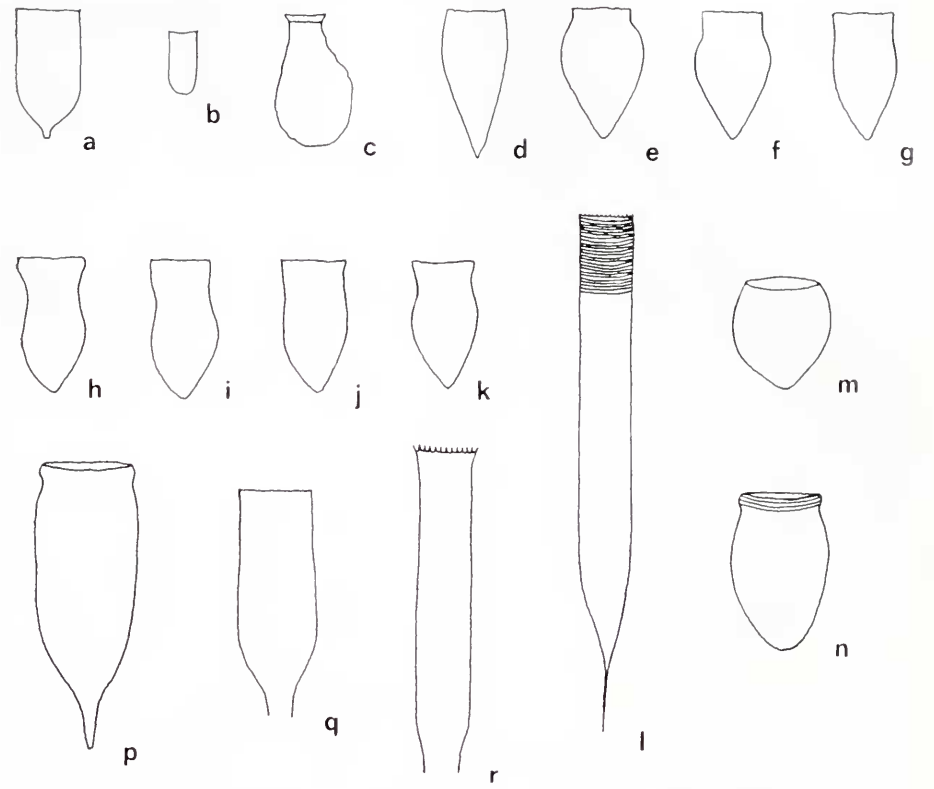

FIGURE 3. Varieties of loricae and those not viewed by SEM. Magnification is 400×, except for *Favella ehrenbergii* (p) 200×. (a) *Tintinnopsis levigata,* (b) *T. minuta,* (c) *T. nucula,* (d–g) *T. rapa,* (h–k) *T. sufflata,* (l) *Helicostomella subulata,* (m) *Metacylis* sp., (n) *Metacylis* sp., (p) *Favella ehrenbergii,* (q) *Tintinnus angustatus,* (r) *T. pectinis.*

1975c); the length, on the other hand, often varied considerably, so a range is given for this dimension.

The sizes of the particles that were accumulated by agglutinating species, as well as the major categories of materials utilized (biogenic or nonbiogenic), are summarized below. It is noteworthy that the particles surrounding the oral aperture of certain species loricae were smaller than the grains found elsewhere on the lorica. The arenaceous *Tintinnopsis* and *Stenosemella ventricosa* in particular, showed selectivity for particle sizes rather clearly. The range of particle sizes around the neck of *T. rapa* and *S. ventricosa* was less than 1–4 μm, in contrast to particles up to 8 and 14 μm, respectively, elsewhere on the lorica.

Three representative particles attached to arenaceous loricae of *S. ventricosa* and *Tintinnopsis* sp. were subjected to electron probe analysis. The principal peak resulted from silicon with very minor amounts of calcium and potassium present, these being almost undetectable in one analysis. Thus we consider the principal grain type to be quartz.

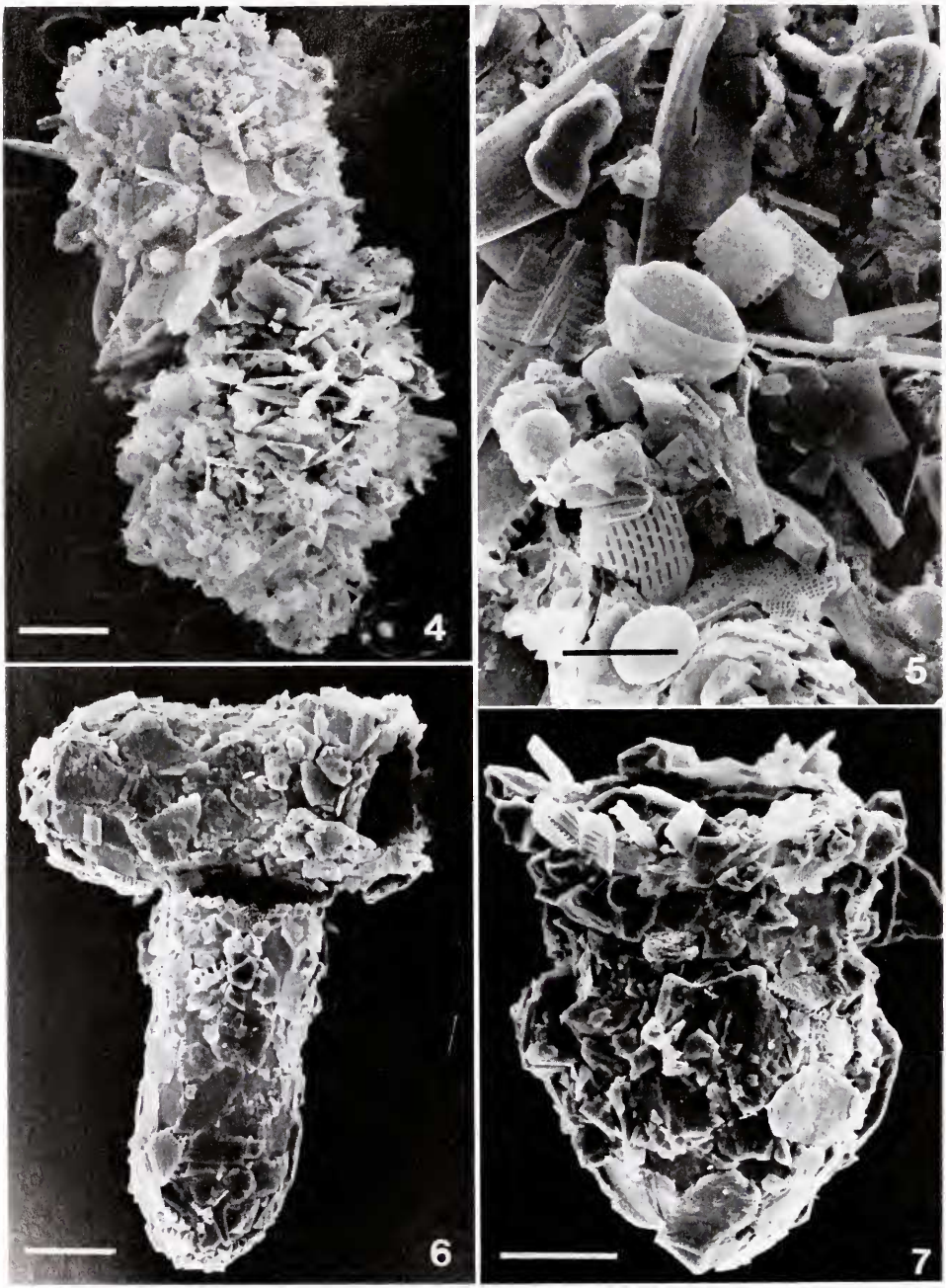

FIGURE 4. Lorica of *Tintinnidium fluviatile*. Desiccation was by the CO_2 critical point drying method to retain the tubular structure. Scale bar equals 15 μm.

FIGURE 5. Portion of an air-dried lorica of *T. fluviatile*. Scale bar equals 7.5 μm.

FIGURE 6. Loricae of *Tintinnopsis acuminata*. Scale bar equals 10 μm.

FIGURE 7. Lorica of *T. baltica*. Scale bar equals 10 μm.

The revised taxonomic scheme of Corliss (1961) is used below in listing the families of Tintinnida of the Woods Hole region. The length of the lorica in μm is denoted by the letter *L; W,* the width in μm; and *n,* the sample size.

Taxonomy

Family Tintinnididae

Tintinnidium fluviatile (Stein) Kent. Figures 4 and 5.

L = 54–164 ($n = 237$); W = 48 ± 5 ($n = 219$). See Fauré-Fremiet, 1924; Kofoid and Campbell, 1929; Silva 1952; Gold and Morales, 1975c. Species agglomerated with particles that are predominantly biogenic in origin; whole diatom frustules may be incorporated. Range of particle sizes utilized less than 2.5–36 μm.

Family Codonellidae

Tintinnopsis acuminata Daday. Figure 6.

L = 31–59 ($n = 2{,}115$); W = 20 ± 1 ($n = 202$). See Kofoid and Campbell, 1929; Marshall, 1969; Gold and Morales, 1975c. Species agglomerated with particles that are mostly nonbiogenic flakes. Biogenic particles include fragments of diatom frustules, etc. Particles surrounding the rim of the lorica are smaller than on the bowl, *e.g.* rim, less than 1–2.5 μm; posteriorly, less than 2–8.5 μm.

T. baltica Brandt. Figure 7.

L = 53–67 ($n = 19$); W = 40 ± 4 ($n = 19$). See Kofoid and Campbell, 1929; Hada, 1937; Balech, 1945, 1948; Silva, 1950; Gold and Morales, 1975c. Species agglomerated with a large proportion of particles of nonbiogenic origin, but also with fragments of diatom frustules (less than 1–6 up to 10 μm).

T. dadayi Kofoid. Figures 8 and 9.

Single flare specimens only: L = 62–81 ($n = 162$); W = 43 ± 2 ($n = 162$). See Kofoid and Campbell, 1929; Durán, 1957; Gold and Morales, 1975c. Species agglomerated with a large proportion of flakes of nonbiogenic origin, but also with considerable biogenic material present including fragments of diatom frustules. Range of particle sizes utilized less than 2–10, up to 15 μm.

T. levigata Kofoid and Campbell. Figure 3a.

L = 41–57 ($n = 26$); W = 22 ± 1 ($n = 26$). See Kofoid and Campbell, 1929; Silva; 1950; Durán, 1965; Marshall, 1969; Gold and Morales, 1975b, 1975c. Referred to as *T. strigosa* (Gold and Morales, 1975b). Not viewed

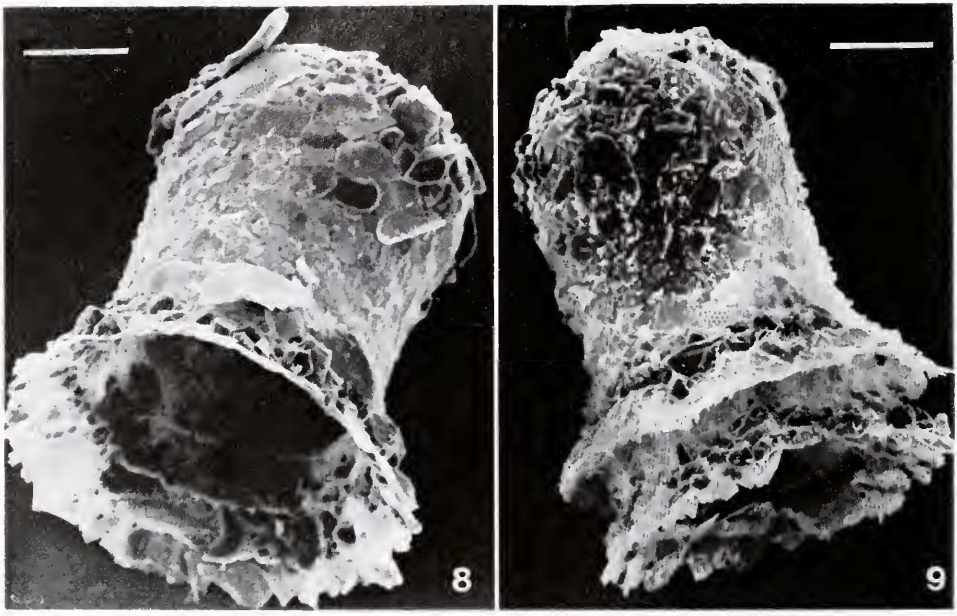

FIGURE 8. Lorica of *T. dadayi* showing spiral structure. Scale bar equals 15 μm.
FIGURE 9. Lorica of *T. dadayi* believed to be an advanced developmental stage produced by the posterior product of division following fission. Scale bar equals 17 μm.

in SEM. Lorica appears heavily agglomerated in light microscope. Posterior horn is closed in this variety.

T. minuta Wailes. Figure 3b.

L = 18–34 ($n = 87$); W = 13 ± 1 ($n = 71$). See Kofoid and Campbell, 1929; Hada, 1938; Wailes, 1943; Marshall, 1969; Gold and Morales, 1975c. Also referred to as *T. nana* (Hada, 1938). Not viewed by SEM; loricae appear lightly agglomerated in light microscope.

T. nucula (Fol) Brandt. Figure 3c.

L = 46; W = 27; oral diameter = 15 ($n = 1$). See Kofoid and Campbell, 1929; Hada, 1938; Silva, 1954. Not viewed by SEM. Lorica appeared heavily agglomerated in light microscope. Though sample size was small, the specimen is included here because it is an unusual and distinctive one.

T. platensis Cunha and Fonseca. Figure 10.

Bowl L = 80–223 ($n = 82$); horn L = 35–76 ($n = 82$); W = 43 ± 2 ($n = 82$). See Cunha and Fonseca, 1912; Kofoid and Campbell, 1929; Hada, 1938; Cosper, 1972; Gold and Morales, 1975c. Referred to as *T.*

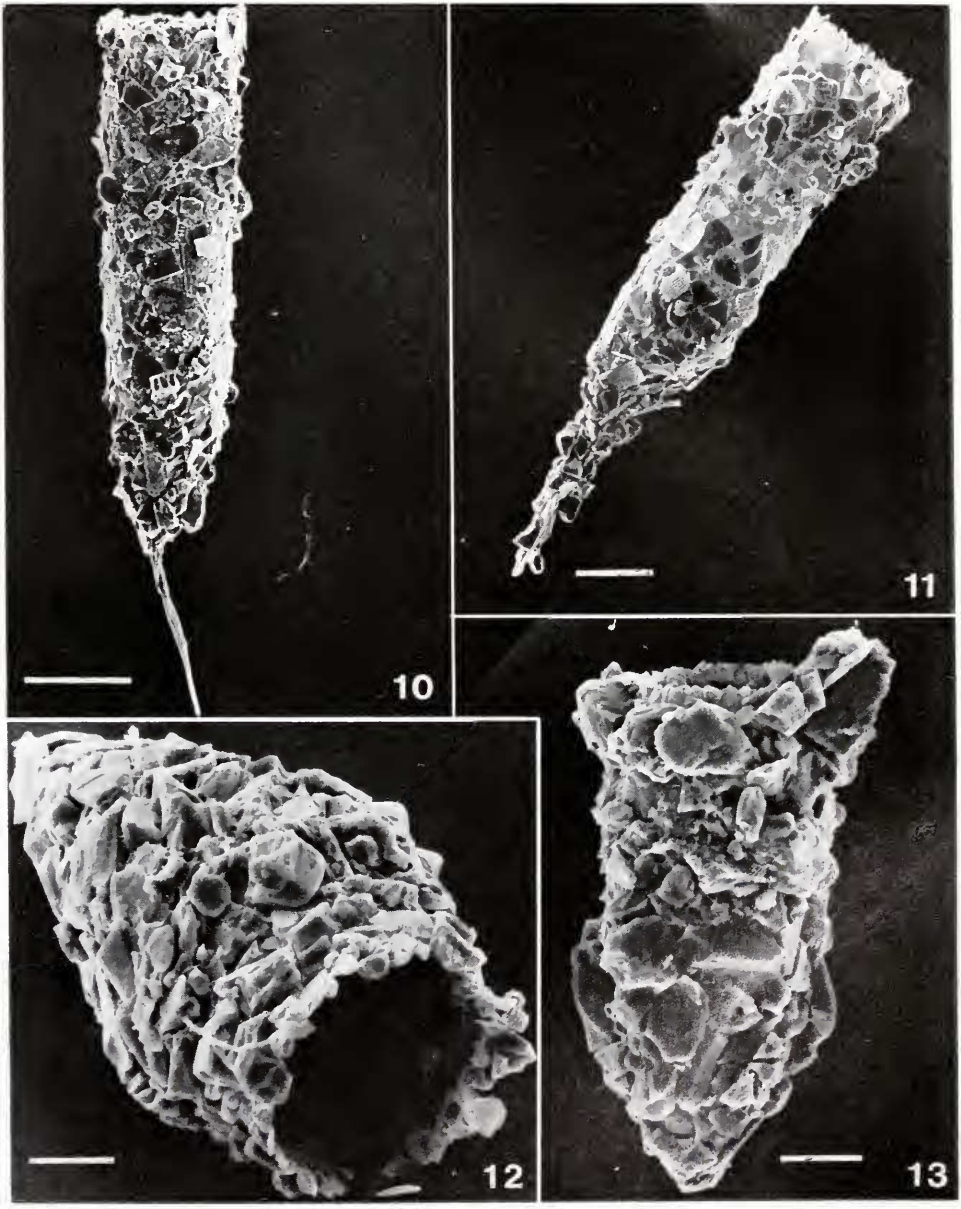

FIGURE 10. Lorica of *T. platensis*. Scale bar equals 32.5 μm.
FIGURE 11. Lorica of *T. radix*. Scale bar equals 20 μm.
FIGURE 12. Lorica of *T. rapa*. Scale bar equals 6 μm.
FIGURE 13. Lorica of *T. sufflata*. Scale bar equals 7 μm.

davidoffi (Calkins, 1902); renamed *Stylicauda platensis* (Balech, 1951). Species agglomerated with both biogenic and nonbiogenic particles, with flakes being the predominant nonbiogenic variety. Range of particle sizes utilized less than 2–13 up to 25 μm. Horn entirely unagglomerated and

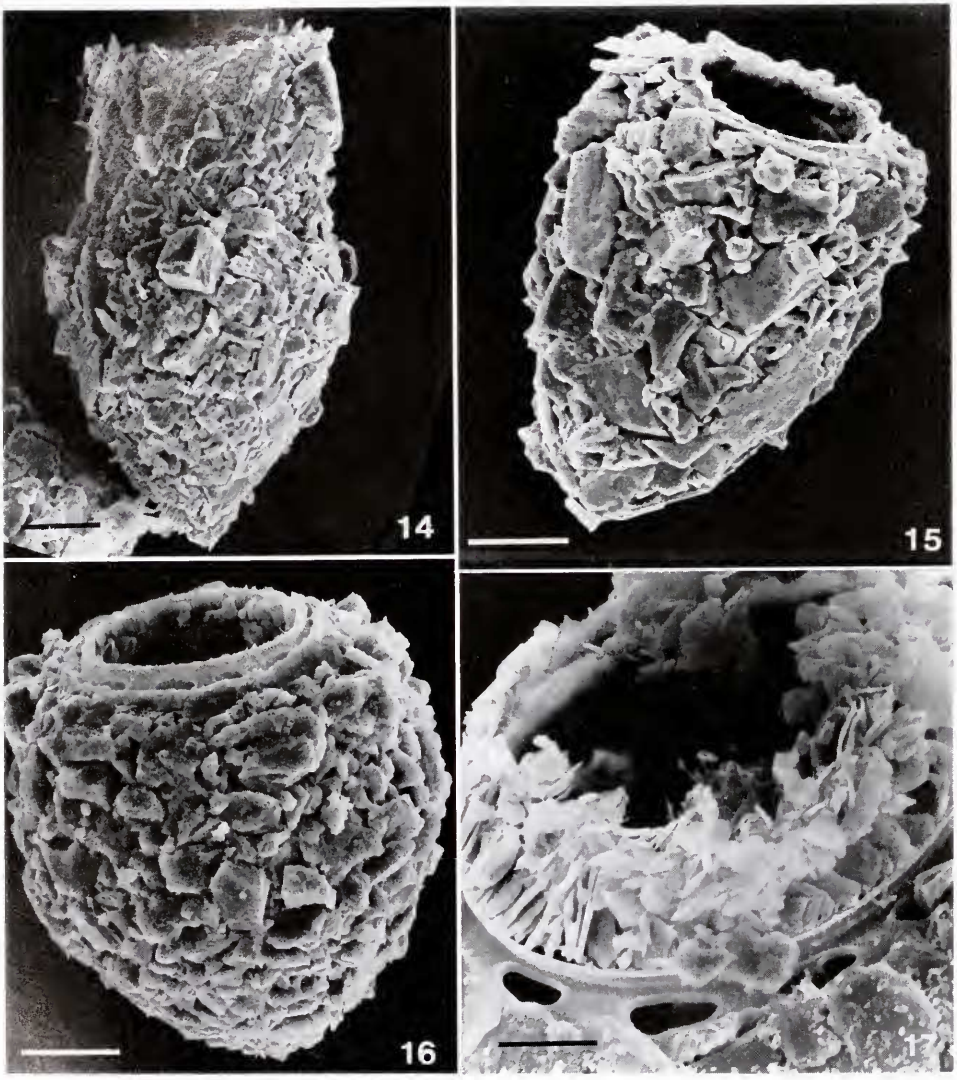

FIGURE 14. Lorica of *T. vasculum*. Scale bar equals 10 μm.
FIGURE 15. Lorica of *Stenoscmella oliva*. Scale bar equals 11 μm.
FIGURE 16. Lorica of *S. ventricosa*. Scale bar equals 16 μm.
FIGURE 17. Anterior region of an *S. ventricosa* lorica showing fenestrae, smaller particles, and in the center, cilia of the contracted cell within. Scale bar equals 6.5 μm.

hyaline. No spiral structure evident as reported by Balech (1951) and Cosper (1972).

T. radix (Imhof) Brandt. Figure 11.

L (includes horn) = 114–198 ($n = 10$); W = 36 ± 1 ($n = 10$). See Hada, 1937, 1938; Balech, 1945; Cosper, 1972. Agglomerated with nonbiogenic particles, mostly flakes but also some grains. Biogenic particles also present. Great variability in length of horn (possibly broken during collection) gives extensive length range.

T. rapa Meunier. Figures 3d–g and 12.

L = 39–58 ($n = 103$); W = 23 ± 2 ($n = 92$). Variety (Figure 3e): L = 38–56 ($n = 28$); W = 28 ± 2 ($n = 28$); oral diameter = 22 ± 2 ($n = 28$). See Kofoid and Campbell, 1929; Hada 1937; Gaarder, 1946; Silva, 1952; Marshall, 1969; Gold and Morales, 1975c. Lorica has an arenaceous appearance due to the high proportion of nonbiogenic particles (mostly grains, but some flakes). Anterior rim consists of small particles (less than 1–4 μm); larger particles elsewhere on bowl (less than 1.5–8 up to 21 μm). Much polymorphic variability evident in Woods Hole specimens (see Figure 3). Confirms Hada's (1937) observation, namely, much variability in size and in length of the aboral conical region.

T. sufflata Hada. Figures 3h–k and 13.

L = 40–64 ($n = 121$); W = 22 ± 2 ($n = 121$). See Hada (1937) which shows specimens with an aboral aperture. The form of the lorica is similar to *T. rapa*; differs, however, in presence of constriction in middle of lorica and very slight widening anteriorly. Both species loricae constructed primarily with nonbiogenic grains. A rim of small particles has been found at the anterior opening.

T. vasculum Meunier. Figure 14.

L = 76–82 ($n = 5$); W = 49 ± 1 ($n = 4$); oral diameter = 39 ± 3 ($n = 5$). See Silva, 1954; Marshall, 1969; Gold and Morales, 1975c. Lorica has an arenaceous appearance due to the almost exclusive use of nonbiogenic grains of uniform size. The particles are presumed to be quartz. Particles are small for a lorica of this size (less than 1.5–6 up to 10 μm).

Family Codonellopsidae

Stenosemella oliva Meunier. Figure 15.

Bowl L = 48–68 ($n = 436$); W = 39 ± 2 ($n = 361$); collar = 25 ± 3 ($n = 166$). See Kofoid and Campbell, 1929; Gaarder, 1946; Durán, 1965; Marshall, 1969; Gold and Morales, 1975c. Lorica has an arenaceous ap-

pearance due to the high proportion of particles of nonbiogenic origin. Grain sizes are less than 1.5–13 up to 16 μm. The oval fenestrae present in the hyaline collar are often obscured by small flakes of nonbiogenic material that adhere.

S. ventricosa Claparède and Lachmann. Figures 16 and 17.

Bowl L = 72–86 ($n = 80$); W = 72 ± 3 ($n = 80$); collar = 41 ± 3 ($n = 77$). See Kofoid and Campbell, 1929; Gaarder, 1946; Silva, 1950; Durán, 1957; Balech, 1959; Marshall, 1969; Gold and Morales, 1975c. Lorica has an arenaceous appearance due to the high proportion of particles of nonbiogenic origin. The range of sizes of grains on the bowl was less than 2–14 up to 25 μm. Flakes usually present around the hyaline collar (sizes less than 1–3.5 μm); often obscure it and hide the oval fenestrae. Representative particles on the bowl were analyzed by electron probe and were determined to be quartz.

Family Coxliellidae

Helicostomella subulata Ehrenberg. Figure 3l.

L = 134–242 ($n = 4$); W = 20 ± 1.5 ($n = 4$). See Kofoid and Campbell, 1929; Hada, 1937; Wailes, 1943; Marshall, 1969; Gold and Morales, 1975c. Lorica hyaline, narrow and cylindrical; tapers aborally to form a long, pointed horn. Anterior rim serrated; spiral structure prominent.

Metacylis sp. Figure 3m.

L = 44–56 ($n = 14$); W = 40 ± 2 ($n = 11$); oral diameter = 32 ± 1 ($n = 14$). Lorica hyaline without collar; widest in middle, narrows posteriorly forming a blunt point. Appears to be a new species.

Metacylis sp. Figure 3n.

L = 57; W = 40; oral diameter = 33 ($n = 1$). See Cosper, 1972. Lorica hyaline. Rim with 2–3 rings; indents below rim forming elongated rounded bowl.

Family Ptychocylididae

Favella ehrenbergii Claparède and Lachmann. Figure 3p.

L = 159–218 ($n = 35$); W = 70 ± 2 ($n = 35$). See Kofoid and Campbell, 1929; Marshall, 1969; Gold and Morales, 1975c. Conspicuous by its absence from the plankton in 1975; dimensions given are from 1974. Large hyaline lorica with short aboral horn present. Constriction present immediately below anterior rim. Irregular polygonal structure visible at 1000 ×.

Family Tintinnidae

Tintinnus angustatus Daday. Figure 3q.

L = 93–118 ($n = 15$); W = 35 ± 2 ($n = 15$); aboral opening = 14 ± 2 ($n = 15$). See Kofoid and Campbell, 1929; Hada, 1938. Lorica hyaline, elongate, slightly expanding posteriorly, then narrows to aboral opening.

T. pectinis Kofoid and Campbell. Figure 3r.

L = 125–171 ($n = 69$); W = 22 ± 1 ($n = 69$). See Kofoid and Campbell, 1929; Wailes, 1943. Lorica hyaline, slightly tapered posteriorly. Anterior rim serrated; open aborally.

Discussion

Some of the methods suggested to account for lorica building by tintinnids were summarized by Tappan and Loeblich (1968). None of the hypotheses took into account the possibility that construction could take place in the sediments or at the sediment-water interface. The attractiveness of this hypothesis, suggested first by Gold and Morales (1975b, 1976), is that these locations would provide easy access to the materials that seem to be actively selected for lorica building by certain species. In these studies, four distinctly different processes of lorica building were discerned by SEM; they are, from all appearances, significant at the generic level. The following are cited as representatives of the different developmental processes: *Tintinnidium fluviatile* (Fig. 4); *Tintinnopsis acuminata* (Figure 6); *Tintinnopsis rapa* (Fig. 12); and *Stenosemella ventricosa* (Fig. 16).

Loricae of *Tintinnidium fluviatile* appear to be relatively soft in consistency. Unless the cell has been fixed quickly and is retained within the lorica, the structure can easily go unnoticed in a preserved sample due to its resemblance to a clump of detritus. The specimen shown in Figure 4 was removed from the plankton while the organism was swimming and then placed in the preservative. This assured that the structures photographed were loricae and not detritus. The adhering particles are extremely varied and large by comparison with the sizes of particles on other species loricae. It is noteworthy that this was the only species where entire diatom frustules were found adhering to the lorica. The appearance of the lorica and the apparent indiscriminate uptake of particles, indicates that particle accumulation by this species is random and perhaps a passive process by comparison with the methods discussed below.

Various *Tintinnopsis* species have been grown *in vitro* (*e.g.*, Gold, 1968, 1973); in the absence of added particles, each has been found to produce a clear, organic lorica. Presumably, a similar structure lies beneath the particles on the *T. acuminata* lorica and on other *Tintinnopsis* that have a similar agglomerated appearance, *e.g.*, *T. platensis*, *T. dadayi*, *T. baltica*. A spiral structure is visible on the *T. dadayi* lorica shown in Figure 8. It can be assumed from the appearance of these loricae, and it was also demonstrated experimentally by the addition of small particles to cultures, that the organic matrix of the lorica is adhesive or is coated with an adhesive substance. *Tintinnopsis* spp. have specialized cilia used in molding the anterior lip of the lorica (Gold, 1968); manipulation by these membranelles,

along with passive accumulation by adhesion, seem to be the methods of particle accumulation used by this group of organisms.

The designation *Tintinnopsis* is used tentatively for *T. rapa*. The lorica construction is obviously different from that of *T. acuminata* described previously. Nevertheless, using accepted taxonomic criteria, namely size and the shape of the lorica, this specimen is deemed to be correctly identified. The particles utilized by this species appear to be almost exclusively quartz. Particle selectivity is strongly suggested by the appearance, but selection for the habitat in which the lorica is produced is an alternative explanation for the species using only quartz particles. The presence of particles at the rim that are smaller than elsewhere on the lorica also suggests selectivity, but this too could be the result of selecting a certain habitat for lengthening the lorica. These loricae are arenaceous, by the definition given previously, and may or may not have an organic lining beneath the particles. It seems more likely, however, that the particles are simply cemented together to form the bowl, and that extensions are made possible by an adhesive being applied at the rim and the organism darting to the sediments where it encounters minute quartz particles. Since the accumulation of particles by this species demonstrates some selectivity, particle uptake by organisms such as *T. rapa* is considered to be an active process.

There are similarities seen in the construction method used by *Stenosemella ventricosa* and the method used by *T. rapa*. In both species, some selectivity has occurred for the types of particles utilized and for their sizes. The appearance of such loricae suggests that this species produces loricae in the sediments by first secreting an organic adhesive in close proximity to the cell membrane. Once the organic matrix has been coated with particles, the cell leaves the sediments and takes up its planktonic existence. These loricae are elongated throughout the life history of the cell, by adhesion of particles in the collar region; when abundant, they may obscure this hyaline structure.

The observed changes in the daily mean lorica lengths reported for *T. acuminata* are interpreted as being the result of cell division and lorica growth processes. We recognize that other possible causes exist that could account for the size differences, *e.g.*, genetic considerations, life history, food availability and its quality. The known fission and lorica building processes, however, seem more likely as explanations. The smallest loricae in the population are interpreted as immature forms, products of the anterior daughter cell following fission. The longest specimens are viewed as representatives of an older age class of loricae. Presumably the posterior daughter that retained the old lorica following cell division continued to add on substance in its normal process of elongation. The observations by Entz (1909), Nie (1933) and Gold (1974) where they suggested that the different sizes of loricae in a population were indicative of age, add support to this explanation.

In the past, a lorica such as the one shown for *T. dadayi* with two flares (Fig. 9), had been considered abnormally developed (Durán, 1957) or an attempt at lorica repair by the cell (Biernacka, 1965). In all likelihood, it is neither; it is viewed here as an entirely normal structure, the second flare being produced by the posterior daughter that had retained the old lorica at the previous fission. Should this be true, such distinctive forms would be extremely useful in determin-

ing the age classes of tintinnids in a plankton sample, in measuring the time between fissions *in situ*, and for determining the lifetime of a cell in the plankton in the presence of predators.

The factors that are responsible for the occurrences of various species throughout the summer months are obscure. Temperature in itself does not appear to be a major contributor to successions during the three months of observations. Dissipation of blooms of tintinnids could sometimes be linked to adverse weather conditions that produced turbulence; it is likely that intensive and variable predation were also major contributors to the disappearance of certain species. Studies are needed in protected tanks or pools to determine more precisely the causes of successions of populations of Tintinnida.

It is beyond the scope of this study to revise the taxonomy of the genus *Tintinnopsis*. It is impossible from these limited observations, to determine which developmental method—that leading to an arenaceous or to an agglomerated appearance—is the more primitive one. Clearly, though, future taxonomic revisions must take into consideration the nature of the particles utilized; more important, the incorporation process itself must be considered.

Summary

The Tintinnida of the Woods Hole, Massachusetts region were identified during two consecutive summers; loricae of eleven species of the agglutinated variety were studied by scanning electron microscopy. There were distinct differences in the types of particles utilized. In some species, quartz was incorporated almost to the exclusion of all other minerals. Biogenic particles such as fragments of diatom frustules, protozoan shells, and coccoliths were conspicuous on a number of species. The authors suggest that this observable difference in the nature of the agglutinated particles is significant at the generic level.

Variability in the sizes and shapes of the lorica of *Tintinnopsis acuminata* and *T. dadayi* are discussed in relation to cell growth and lorica developmental processes.

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